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RIBBON BRIDGE BOAT TRANSPORTER SYSTEM STUDY

Roger M. Atkins, et al

Army Mobility Equipment Research and Development Center
Fort Belvoir, Virginia

October 1972

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RIBBON BRIDGE BOAT TRANSPORTER SYSTEM STUDY

by

R. Atkins
R. Wallace
R. Felts

October 1972

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U. S. ARMY MOBILITY EQUIPMENT RESEARCH AND DEVELOPMENT CENTER
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13. ABSTRACT

This study is directed to a comparison of the relative cost, effectiveness, and risks associated with three bridge erection boat transportation systems for the ribbon bridge. The present boat transportation system is defined as the baseline. Alternative I consists principally of a one-piece boat on a truck transporter/launcher/retriever. Alternative II has a one-piece boat on a trailer pulled by a prime mover. It is concluded that Alternative I is the most cost-effective choice.

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October 1972

Distributed by

The Commanding Officer
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Prepared by

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System Engineering and Computation Support Office

Ib

SUMMARY

This study is directed to a comparison of the relative cost, effectiveness, and risks associated with three bridge erection boat transportation systems for the ribbon bridge. The present boat transportation system is defined as the baseline. Alternative I consists principally of a one-piece boat on a truck transporter/launcher/retriever. Alternative II has a one-piece boat on a trailer pulled by a prime mover. It is concluded that Alternative I is the most cost-effective choice.

FOREWORD

The Systems Engineering and Computation Support Office performed this study for Mr. F. DeFilippis, Program Manager, Bridge Erection Boat Program, during the period 20 July 1972 to 31 August 1972.

The authors wish to express their appreciation to Mr. DeFilippis and to Mr. J. Singleton for their cooperation throughout the study.

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RIBBON BRIDGE BOAT TRANSPORTER SYSTEM STUDY

I. INTRODUCTION

1. **Subject.** This report identifies measures of effectiveness and evaluates two alternatives against the baseline bridge erection boat transporting system.

2. **Background.** The ribbon assault float bridge has been developed to simplify and to speed assault bridge construction. Launching a ribbon bridge bay is a simple 3- to 5-minute operation. Each bay can be transported, launched, and retrieved by a single 5-ton bridge bay transporter. In order to realize the full time saving afforded by the fast launch ribbon bridge bays, the bridge erection boats must meet the transportation, launch, and retrieval standards of the bridge bays. The present baseline boat/transporter system does not meet these requirements. In an attempt to solve this problem, two alternative boat/transporter systems are being considered. Very briefly, the baseline and two alternatives (Fig. 1) consist of:

a. **Baseline.**

(1) 1/2 boat, cradle, and 2½-ton truck
(2) 1/2 boat, cradle, and trailer
(3) 20-ton crane

b. **Alternative I.** Single-piece boat, cradle, modified 5-ton truck

c. **Alternative II.**

(1) Single-piece boat, cradle, 5-ton trailer (special)
(2) Prime mover, such as 2½-ton truck

The one-piece bridge erection boat has the following characteristics: approximately 27 feet long; approximately 9 feet wide; about 8,000 to 10,000 pounds; capable of being launched in 30 inches of water. Additional information relevant to this study is available.[1,2,3,4,5]

---

[1]TOE 5-79T, Assault Float Bridge Company, Ribbon.

[2]TOE 5-78G, Engineer Float Bridge Company.

[3]Proposed Material Need (Production) (MN(P)).

[4]Draft Proposed Material Need-Abbreviated (DPMN(A)) for Improved Bridge Erection Boat.

[5]Taylor, William B., "Military Bridging, Status and Trends," The Military Engineer, Vol. 63, No. 416, Nov.-Dec. 1971, p. 417.

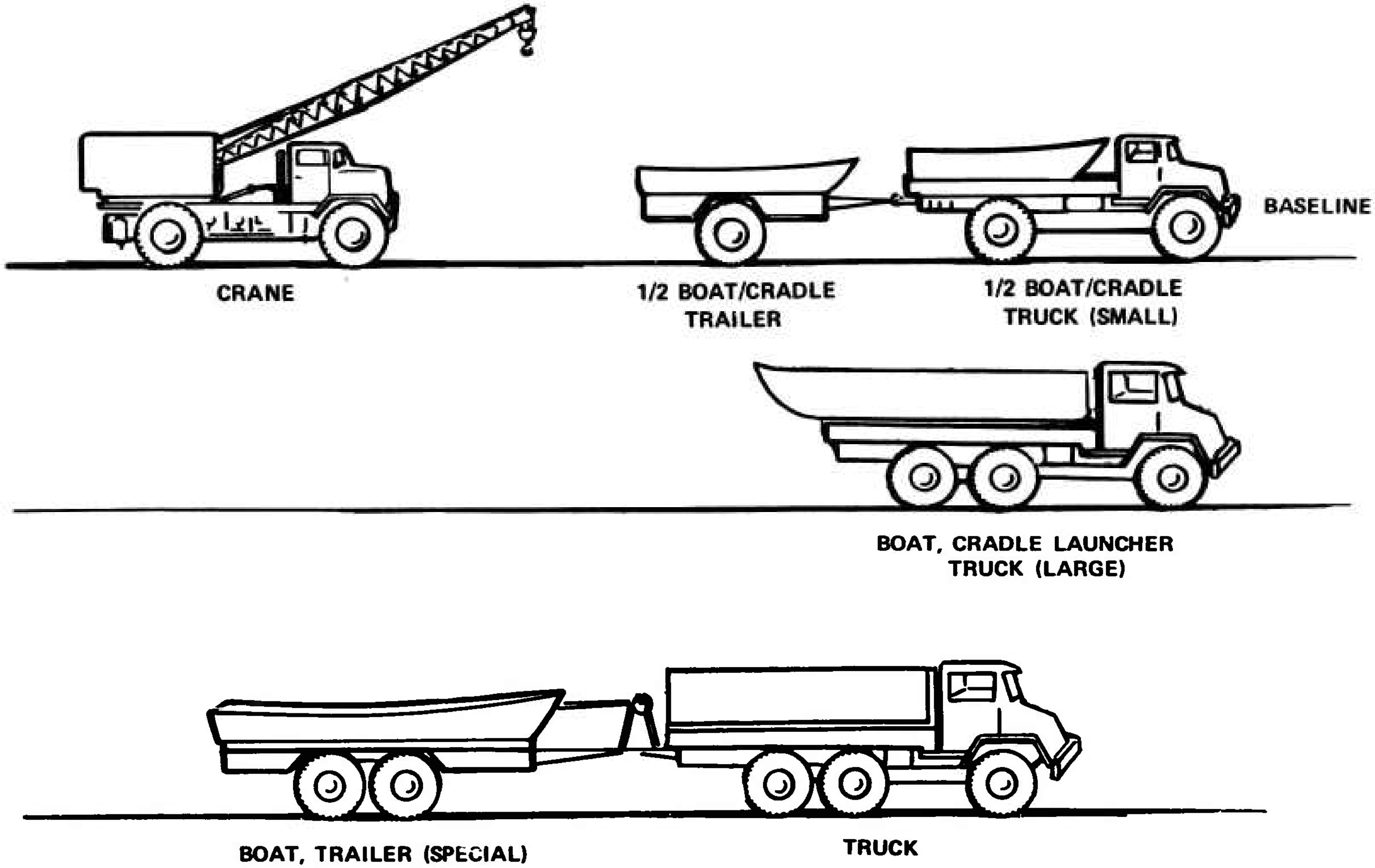

Fig. 1. Bridge erection boat transporter systems.

II. INVESTIGATION

3. **Approach to the Problem.** In order to view this study in the proper perspective, top and first level function flow block diagrams (see Appendix A) have been developed for the total ribbon bridge system. Additional function flow block diagrams (Figs. 2 through 5) deal specifically with the transport/launch/retrieve system/bridge erection boat. This definition provides a visible track of rationale from function requirements to boat transportation systems evaluation.

After measures of effectiveness were derived and defined, functional time requirements were estimated by means of questionnaires submitted to military personnel experienced in bridging operations. Costs for the major equipment of each transporter system were taken from SB-700-20[6] and, where necessary, from estimates by knowledgeable bridge engineers. Since time did not permit a probabilistic evaluation of the measures of effectiveness for system comparison, a simple rating method was devised. The baseline was considered to have an arbitrary rating of 3 for each measure and the two alternatives were rated 1 through 5, where 1 indicated the worst rating and 5 the best. This comparison is shown in Table I.

The cost figures for the three systems are depicted in Tables II, III, and IV. Costs shown in parentheses are estimates; all others are from SB-700-20.[7] Only the major equipment for the two float bridge platoons and the equipment and maintenance platoon was tabulated.

Two scenarios were chosen, a best and worst case, to be used to define operational time and manpower limits or ranges of values.

[6] SB-700-20, Army Adopted/Other Selected Items and a List of Reportable Items, dated May 1971.

[7] SB-700-20, Army Adopted/Other Selected Items and a List of Reportable Items, dated May 1971.

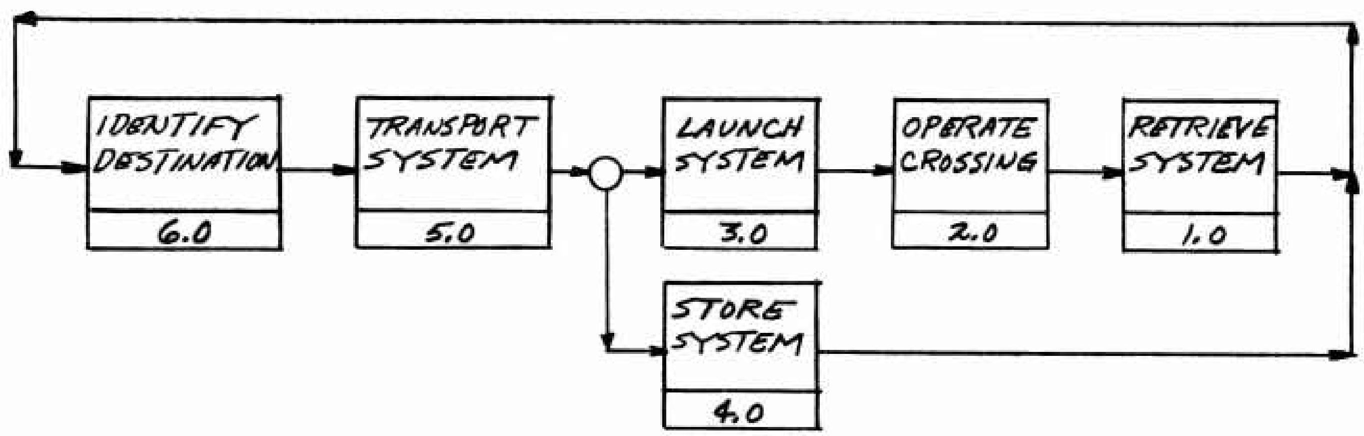

Fig. 2. Transport-launch-retrieve system bridge erection boat function flow block diagram, top level.

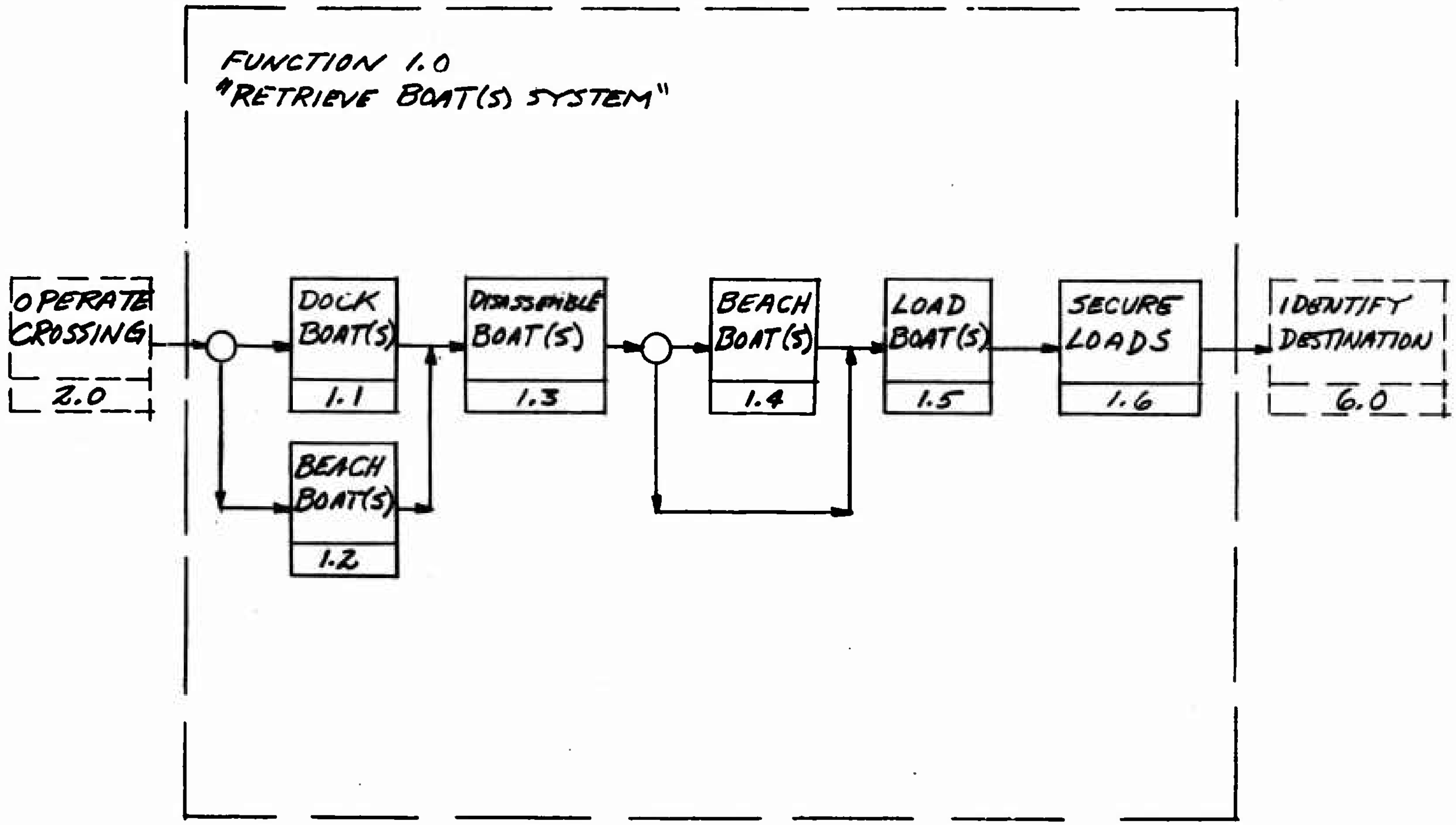

Fig. 3. Retrieve boat system function flow block diagram, first level.

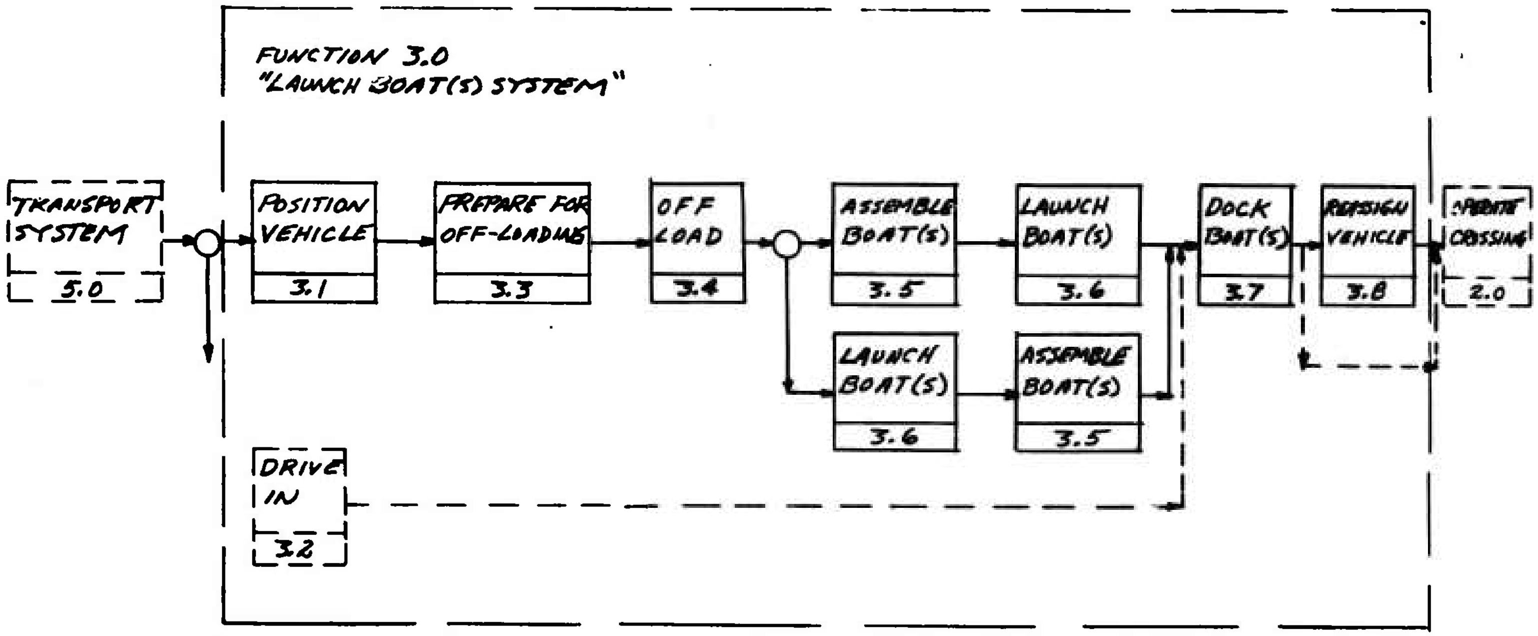

Fig. 4. Launch boat system function flow block diagram, first level.

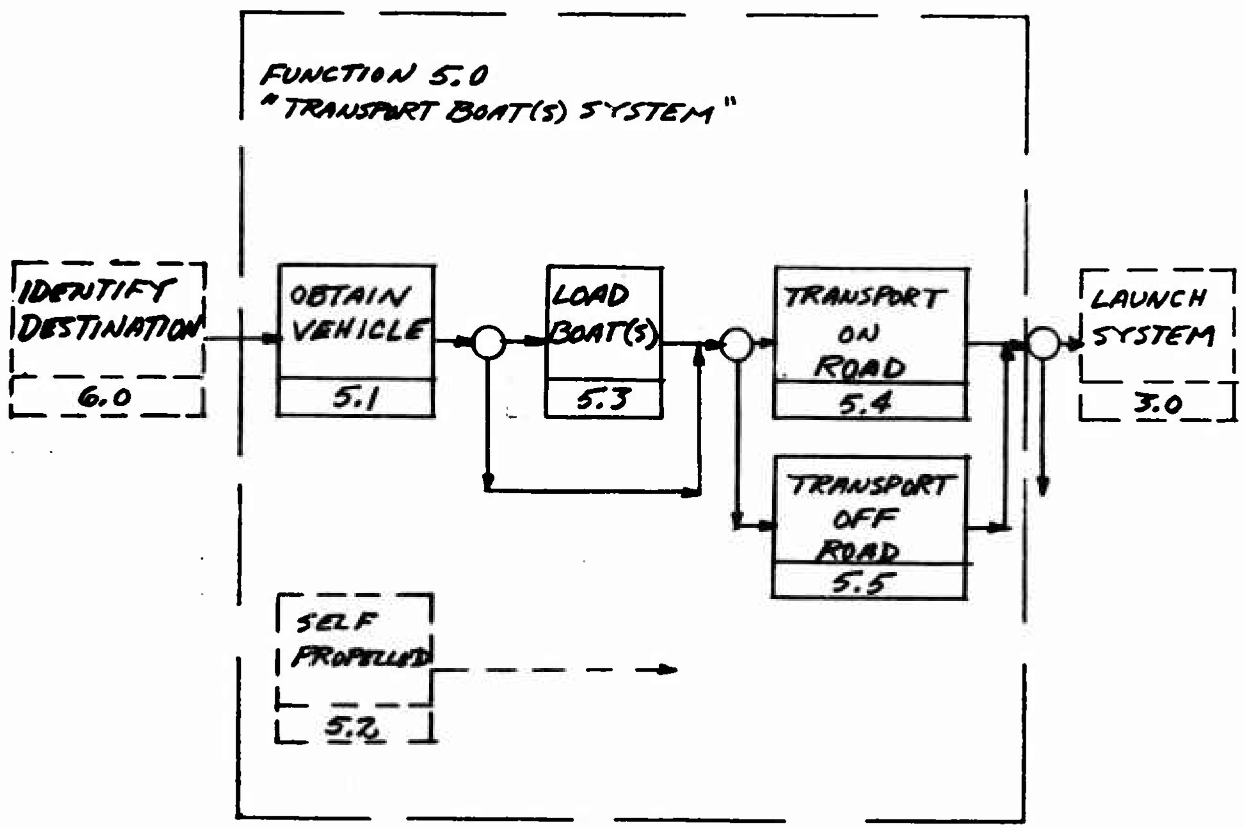

Fig. 5. Transport boat(s) system function flow block diagram, first level.

Table I. Bridge Erection Boat Transporter System,
Evaluation of Alternative Concepts
(1 = worst; 5 = best)

Measures of Effectiveness, Costs, and Management Risks	Baseline	Alternative I (Boat Truck)	Alternative II (Boat Trailer)
I. Measures of Effectiveness			
A. Availability	24	32	30
1. Initial Deployment Mobility	3	4	4
2. Field Mobility	3	4	4
3. Scheduled Maintenance	3	4	4
4. Checkout Time	3	4	4
5. Repair Time	3	4	4
6. MTB Maintenance Actions	3	4	3
7. Commonality	3	4	3
8. Deadline	3	4	4
B. Dependability	18	26	24
1. Maintainability	3	4	4
2. MTB Failure	3	4	4
3. Degradation Modes	3	4	4
4. MTB Overhaul	3	4	4
5. Accident Susceptibility	3	5	4
6. Vulnerability to Enemy Actions	3	5	4
C. Capability	42	59	54
1. Launchability/Retrievability			
a. Time	3	5	4
b. Number of Troops	3	4	4
c. Simplicity = 1/No. Steps	3	5	4
d. Adaptability = $T_{ws} - T_{bs} \rightarrow 0$	3	4	4
2. Mobility			
a. Speed			
(1) On Road (mph)	3	4	4
(2) Off Road (mph)	3	5	4

Table I (cont'd)

Measures of Effectiveness, Costs, and Management Risks		Baseline	Alternative I (Boat Truck)	Alternative II (Boat Trailer)
b. Maneuverability				
(1) Turn Radius		3	3	3
(2) Width		3	4	4
(3) Length		3	4	4
(4) Weight–Total		3	4	4
(5) Driver Skill		3	5	4
3. Logistics Factor = 1/No. Pieces		3	5	4
4. Endurance Factor		3	4	4
5. Compatibility		3	3	3
D. Effectiveness (A X D X C)	Gross	18,144	49,088	38,880
	Adjusted	1.0	2.7	2.1
II. Costs				
A. Operations Hardware		3	3	3
B. Operations Personnel		3	4	4
C. Operations Time		3	5	5
D. Operations Labor		3	4	4
III. Management Risks				
A. Cost		3	2	2
B. Performance		3	2	2
C. Schedule		3	2	2

Table II. Bridge Erection Boat Transporter System, Baseline Costs

Equipment		Unit		
Lin	Abv. Descr.	Cost	No.	Bridge
Z10981	Ramp Bay	(50,000)	12	600,000
Z10976	Interior Bay	(36,000)	30	1,080,000
Z10986	Bridge Transporter	(28,000)	42	1,176,000
Z76358	Supplemental Set	(15,000)	2	30,000
X60833	Truck, Utility, 1/4-ton	3,238	2	6,476
B83582	Boat, Bridge Erection (27-ft)	28,661	18	515,898
X40009	Truck Cargo, 2½ ton	9,380	18	168,840
X43845	Truck, Dump, 5-ton	16,553	2	33,106
F39378	Crane, 20-ton RT	75,000	2	150,000
W76816	Dozer, FT	32,916	2	65,832
X63299	Wrecker, 5-ton	27,824	1	27,824
P11866	Pneumatic Tool/Comp Set	11,230	1	11,230
574832(?)	Repair Parts Van	13,451	1	13,451
X54120(?)	Maintenance Truck (Contact)	11,621	2	23,242
T13152	Organ. Repair Shop (Truck Mounted)	47,560	1	47,560
V12141	Tank and Pump Units	2,822	2	5,644
Y48118	Welding Set Arc Inert Gas	519	2	1,038
W94441(?)	Trailer, Boat	1,200	18	21,600
		410,975		3,977,741

Notes:
1. ( ) Estimated by J. Singleton
2. Co less Hdq Plt

Table III. Bridge Erection Boat Transporter System, Alternative I Costs

Equipment		Unit		
Lin	Abv. Descr.	Cost	No.	Bridge
Z10981	Ramp Bay	(50,000)	12	600,000
Z10976	Interior Bay	(36,000)	30	1,080,000
Z10986	Bridge Transporter	(28,000)	42	1,176,000
Z76358	Supplemental Set	(15,000)	2	30,000
X60833	Truck, Utility, 1/4-ton	3,238		
B83582	Boat, Bridge Erection (27-ft)	28,661	18	515,898
--	Truck, Boat, 5-ton (special)	(30,000)	18	540,000
X43845	Truck, Dump, 5-ton	16,553	2	33,106
W76816	Dozer, FT	32,916	2	65,832
X63299	Wrecker, 5-ton	27,824	1	27,824
P11866	Pneumatic Tool/Comp Set	11,230	1	11,230
S74832(?)	Repair Parts Van	13,451	1	13,451
X54120(?)	Maintenance Truck (Contact)	11,621	2	23,242
T13152	Organ. Repair Shop (Truck Mounted)	47,560	1	47,560
V12141	Tank & Pump Units	2,822	2	5,644
Y48118	Welding Set Arc Inert Gas	519	2	1,038
				4,177,301

Notes:

1. (   ) Estimated by J. Singleton
2. Co less Hdq Plt

Table IV. Bridge Erection Boat Transporter System, Alternative II Costs

Equipment		Unit		
Lin	Abv. Descr.	Cost	No.	Bridge
Z10981	Ramp Bay	(50,000)	12	600,000
Z10976	Interior Bay	(36,000)	30	1,080,000
Z10986	Bridge Transporter	(28,000)	42	1,176,000
Z76358	Supplemental Set	(15,000)	2	30,000
X60833	Truck, Utility, 1/4-ton	3,238	2	6,476
B83582	Boat, Bridge Erection (27-ft)	28,661	18	515,898
--	Trailer, Boat, 5-ton	(10,000)	18	180,000
X40009	Truck, Cargo, 2½-ton	9,380	18	168,840
X43845	Truck, Dump, 5-ton	16,553	2	33,106
W76816	Dozer, FT	32,916	2	65,832
X63299	Wrecker, 5-ton	27,824	1	27,824
P11866	Pneumatic Tool/Comp Set	11,230	1	11,230
X74832(?)	Repair Parts Van	13,451	1	13,451
X54120(?)	Maint. Truck (Contact)	11,621	2	23,242
T13152	Organ. Repair Shop (Truck mounted)	47,560	1	47,560
V12141	Tank & Pump Units	2,822	2	5,644
Y48118	Welding Set Arc Inert Gas	519	2	1,038
				3,986,141

Notes:
1. (   ) Estimated by J. Singleton
2. Co less Hdq Plt

III. DISCUSSION

4. **Measures of Effectiveness.** Effectiveness is defined[8] as a measure of the extent to which a system may be expected to achieve a set of specific mission requirements. It is a function of the system's availability, dependability, and capability. The basic approach for evaluating the effectiveness of a system can be empirical or analytical.

Availability, dependability, and capability are separate components that are linked by conditional probability. This condition requires that additional measures are significant if and only if previous measures have been fulfilled.

Availability is defined as a measure of system condition at the start of the mission. It normally includes such terms as time between maintenance actions and repair time.

Dependability is defined as a measure of the system condition at one or more points during the mission, given the system condition at the start of the mission. It includes terms associated with reliability and maintainability.

Capability is defined as a measure of the system ability to achieve the mission objectives given the system condition during the mission. Capability specifically accounts for the performance spectrum of the system.

The following measures of effectiveness, which are defined in Appendix B, were identified as applicable to this system.

a. **Availability.**

(1) Initial deployment mobility.
(2) Field mobility.
(3) Scheduled maintenance.
(4) Checkout time.
(5) Repair time.
(6) Mean time between maintenance actions.
(7) Commonality.
(8) Deadline.

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[8] AMCR 706–191

b. Dependability.

(1) Maintainability.
(2) Mean time between failures.
(3) Degradation modes.
(4) Mean time between overhauls.
(5) Accident susceptibility.
(6) Vulnerability.

c. Capability.

(1) Launchability/retrievability.
(2) Time.
(3) Number of troops required
(4) Simplicity.
(5) Adaptability.
(6) Mobility.
  (a) Speed.
    1 On road.
    2 Off road.
  (b) Maneuverability.
    1 Turn radius.
    2 Width.
    3 Length.
    4 Weight.
    5 Driver skill.
  (c) Logistics factor.
  (d) Endurance factor.
  (e) Compatibility.

Although there is no intent, either directly or by implication, to recommend removal of the 20-ton crane from the ribbon bridge equipment, the measures of effectiveness matrix in Table I reflects the increase in effectiveness, particularly availability, that results when a crane is not *required* for system transportation/launch/retrieval. Additionally, a one-piece boat by its very nature further reduces the number of items of equipment required, as well as operations functions of assembly and disassembly and related activities.

In the case of both alternatives, the truck (Alternative I) or the trailer (Alternative II) will generally have to be backed into the water, to a degree depending on the local conditions, to launch and to retrieve the boat. In cases

where the water will be above the rear axle, maintenance problems can arise when a truck (Alternative I) is used, but this problem has been minimized for trailers (Alternative II) since a trailer can have a much simpler axle system with better seals and lubricating points. On the other hand, using the bridge truck with a removal cradle permits greater commonality of equipment and eliminates the need for a special purpose trailer.

The measures of effectiveness matrix in Table I compares ratings which are subjective in nature. It is not the intent of the authors to defend any particular rating, but it is felt that the overall results are reasonable and would not vary greatly regardless of who the analyst might be.

5. **Effectiveness Evaluation.** The bridge erection boat transporter system measures of effectiveness are shown in Table I. Values assigned to the baseline and alternative configurations were based on a scale of 1 to 5, where 1 is worst and 5 is best. For comparison purposes, the baseline system was arbitrarily given an effectiveness rating of 3 in all categories. The numerical values for each system were totaled for each component of effectiveness; i.e., availability, dependability, and capability. Since availability, dependability, and capability are linked by conditional probability, the totals of A, D, and C above were multiplied for each system to give a gross "E" value. These gross values were then adjusted to a baseline effectiveness of 1.0. The resulting effectiveness numbers are not intended to have any absolute significance, but they do provide comparative insight. First, both alternative systems show up as superior to the baseline system. Second, Alternatives I and II rank relatively close together. Third, Alternative I, the boat/truck system, is indicated as more effective than Alternative II, the boat/trailer system.

6. **Costs.**

a. **Operations Hardware.** Due to study time limitations, a hybrid cost basis of "replacement" cost was adopted, which seemed reasonable in light of the mechanical and development similarity of the systems being compared. The major items of equipment for the Assault Float Bridge Company, Ribbon (TOE 5-79T), less that of the Headquarters Platoon, have been itemized, and costs of each item, where possible, were taken by LIN from SB700-20. Where costs were not available in SB 700-20, estimates were obtained from (in most cases) John Singleton, Marine & Bridge Division.

The baseline system major equipment costs about $3,977,740. Alternative I shows a total of approximately $4,177,300, or 5 percent higher than the

baseline, while Alternative II would cost about $3,986,140, which is 0.2 percent more than the baseline. In all cases, $3,637,300 is a common factor and the differences in the items subject to change is, in the worst case, $199,560, which should be not greater than possible errors in estimation. Based on the above, it appears that the three systems have identical "replacement" costs. Therefore, system selection should be based on effectiveness and risk considerations.

b. Operations Personnel. The three systems under consideration appear to require the same amounts of manpower. The personnel delta between Alternative I and Alternative II should be zero. Between the baseline and both alternatives, the maximum delta would be four if the two cranes are eliminated from company equipment, and the minimum delta would be zero if the two cranes are retained. The total present strength for the Ribbon Bridge Company (TOE 5-79T) is 194 men. Therefore, a delta of four is only 2 percent of the allowable baseline.

c. Operations Time. A survey, by means of questionnaires, was conducted using experienced Army bridge personnel. There were separate questionnaires for the baseline system, Alternative I, and Alternative II. Each questionnaire was divided into a "best" and "worst" scenario. The "best" case scenario was for deliberate crossing, little or no enemy fire, low stream velocity, ideal bank/shore, easy terrain approach, and day. The "worst" case scenario was for hasty crossing, probable enemy fire, high stream velocity, difficult bank/shore, difficult terrain approach, and night. For each configuration and each scenario, the questionnaire asked for estimated most probable time and estimated number of troops required for subfunctions of transport, launch, and retrieve.

A study of these time estimates indicates that overall, Alternatives I and II should fulfill the transport/launch/retrieve functions much faster than the baseline configuration does and that there is very little difference between Alternative I and Alternative II from a time standpoint. In all cases, for all configurations, the overall time for the "worst" scenario was about twice that of the "best" scenario.

d. Operations Labor. The questionnaires discussed earlier asked for estimates of the number of troops required for each of the transport/launch/retrieval subfunctions as well as estimated times. In all cases, the number of personnel estimated for the baseline functions was equal to or greater than the number estimated for Alternatives I and II. There was little or no difference between the Alternative I and Alternative II manpower requirements.

The above information, taken in conjunction with the previously discussed time requirements, strongly indicates that the manhours of labor required for the baseline system will be considerably greater than those required for Alternatives I and II and that, again, there is very little difference in labor needed for Alternatives I and II.

7. **Management Risks.**

a. **Cost Risk.** The baseline system components have passed through research, development, and some testing and are approaching type classification for the items not already type classified. The elements of the baseline upon which this study is centered are the bridge erection boat transporters. These transporters have been in use for many years and their cost risk is, for all practical purposes, zero.

Alternative I would replace the baseline 1/2 boat trailer with cradle and 2½-ton truck with cradle with a ribbon bridge transporter with cradle and assorted tiedown, launch, retrieve, etc., hardware. The basic truck used in this bridge transporter is a standard 5-ton cargo truck and would have little or no cost risk associated with it. The special bridge bed, in its present form, has gone through some testing and would present a reasonably small management cost risk. Modifications to the bridge bed plus new items such as the cradle would not increase this risk.

Alternative II would require the design of a special 5-ton boat trailer. Boat trailer design should present no problems, but a nominal cost risk would be associated with the design, manufacture, test, etc.

When compared with the baseline, Alternatives I and II both have a slightly greater cost risk. Alternatives I and II would seem to be at approximately the same cost risk level.

b. **Performance Risk.** The baseline system does not meet the performance requirements of the overall ribbon bridge system in respect to time, which includes transport time, launch time, and retrieval time. The prime transport time weakness is the crane. The assembly and disassembly boat functions require launch and retrieval time additions.

Alternatives I and II both dispense with the crane and both have a one-piece boat that does not require assembly or disassembly. Proper design should insure that either Alternative I or Alternative II can meet transport, launch, and retrieval time requirements. Tests will be necessary to prove this,

however. If Alternative I (boat, truck) is chosen as the baseline replacement system, a very real performance risk stems from water degradation of the rear axle following submergence during either launch or retrieval. The sealing problems in the design of a powered drive axle could impose a performance risk on this approach. The launch velocities and angles of entry, in conjunction with boat draught, length, and weight and water depths, must be considered relative to possible launch limitation risks. Similar risks may exist for the retrieval phase.

Should Alternative II (boat, trailer) be selected, there are possible performance risks associated with trailer travel dynamics. Because of the simpler, non-drive axle, sealing and lubrications should incur a lesser risk than in Alternative I. If an extendable trailer tongue is required, attendant performance risks must be considered.

c. **Schedule Risk.** All components of the baseline system have established records and are therefore compatible with accurate scheduling based on those data. Management risks relative to meeting schedules are slight.

Both Alternatives I and II will incur greater risks of failing to meet schedules than will the baseline. There is no evidence, however, that more than normal scheduling risks would exist or that either Alternative I or II would be more or less prone to such risks.

8. **General.**

The summary of the cost, effectiveness, and risk comparison is shown in Table V.

Table V. Cost, Effectiveness, and Risk Comparison

		Baseline System	Alternative I	Alternative II
1.	Effectiveness (E)			
	Availability (A)	24	32	30
	Dependability (D)	18	26	24
	Capability (C)	42	59	54
	A X D X C = E (Gross)	18,144	49,088	38,880
	(Adjusted)	1.0	2.7	2.1
2.	Cost (Gross)	\$3,977,740	\$4,177,300	\$3,986,140
		1.000	1.050	1.002
3.	Cost-Effectiveness	1.0	0.39	0.47
4.	Risk (1 = high, 3 = low)			
	Cost	3	2	2
	Performance	3	2	2
	Schedule	3	2	2

IV. CONCLUSIONS

9. **Conclusions.** The report concludes that:

a. The "replacement" and operations costs of the baseline and alternative systems are nearly identical (within 5 percent). (See Table V.)

b. The effectiveness of the alternatives is significantly better than the baseline.

c. Alternative I (one-piece boat truck transporter) is slightly more cost-effective than Alternative II and significantly more cost-effective than the baseline.

d. There are no significant cost, performance, or schedule risks associated with either of the alternatives considered.

APPENDIX A

RIBBON BRIDGE SYSTEM FUNCTION FLOW BLOCK DIAGRAMS–TOP LEVEL AND FIRST LEVELS (PRELIMINARY)

BRIDGE-BOAT SYSTEM

Threat: Inability to cross narrow bodies of water, i.e., rivers, streams, inlets, etc.

Need: Bridge System – including transportation to site, launching, maneuver after launching, retrieval, transportation from site.

Assumptions: The already designed ribbon bridge is the bridge component. A boat(s) is to be the maneuver component. DPMN (A), USACDC ACN 15664, documents the improved bridge erection boat requirements.

Problem Areas: Transport to site, launch, compatibility of ribbon bridge components, retrieve, transport from site.

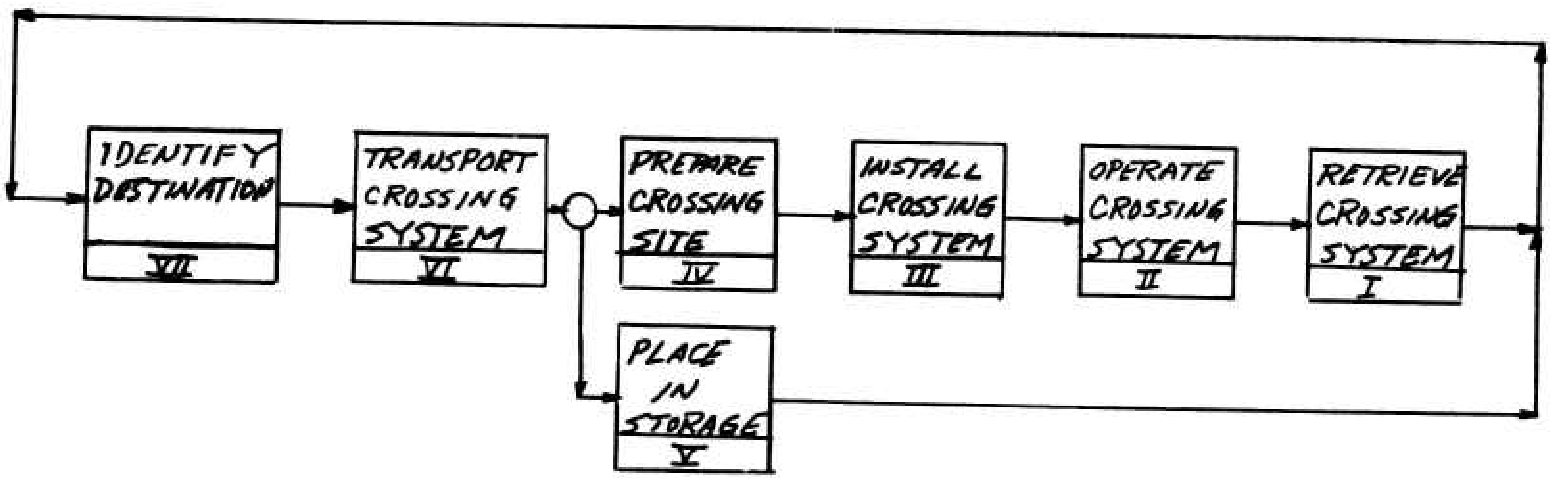

Fig. A-1. Ribbon bridge system function flow block diagram, top level.

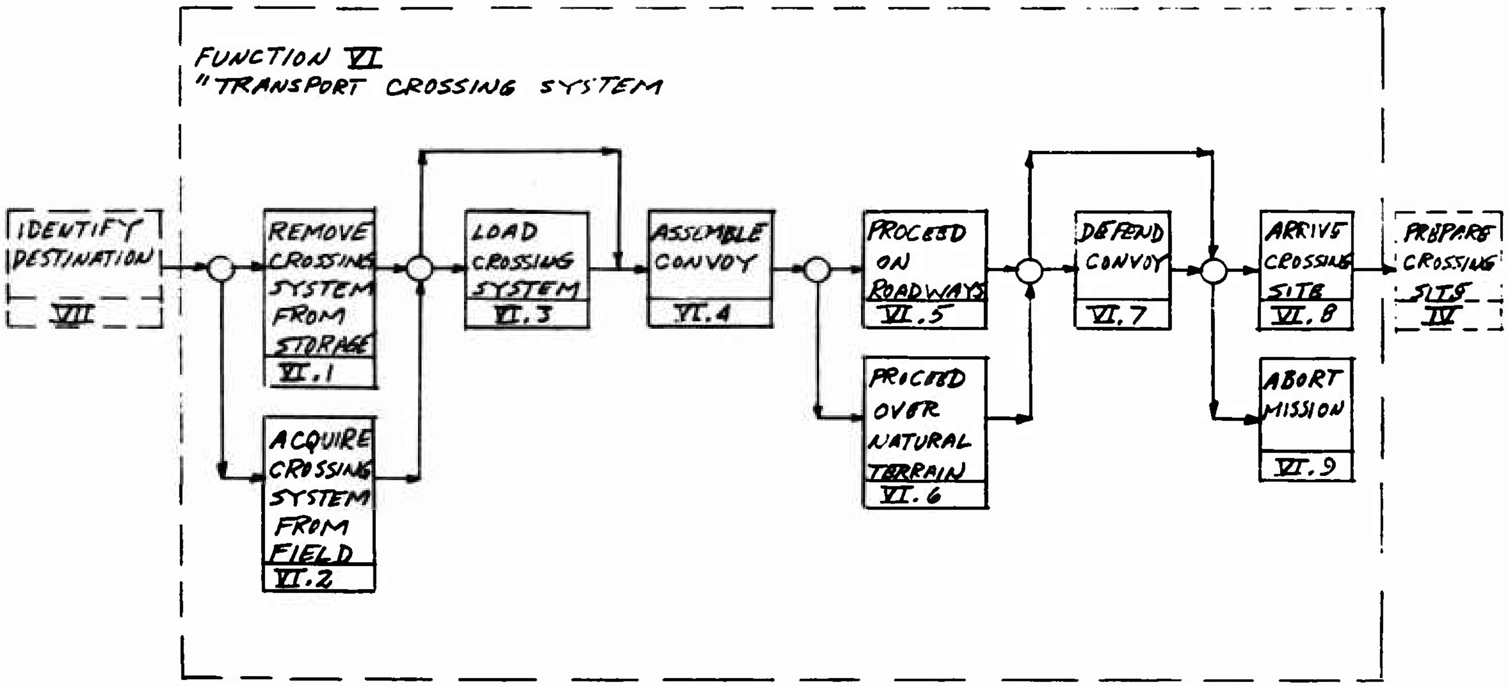

Fig. A-2. Transport crossing system function flow block diagram, first level.

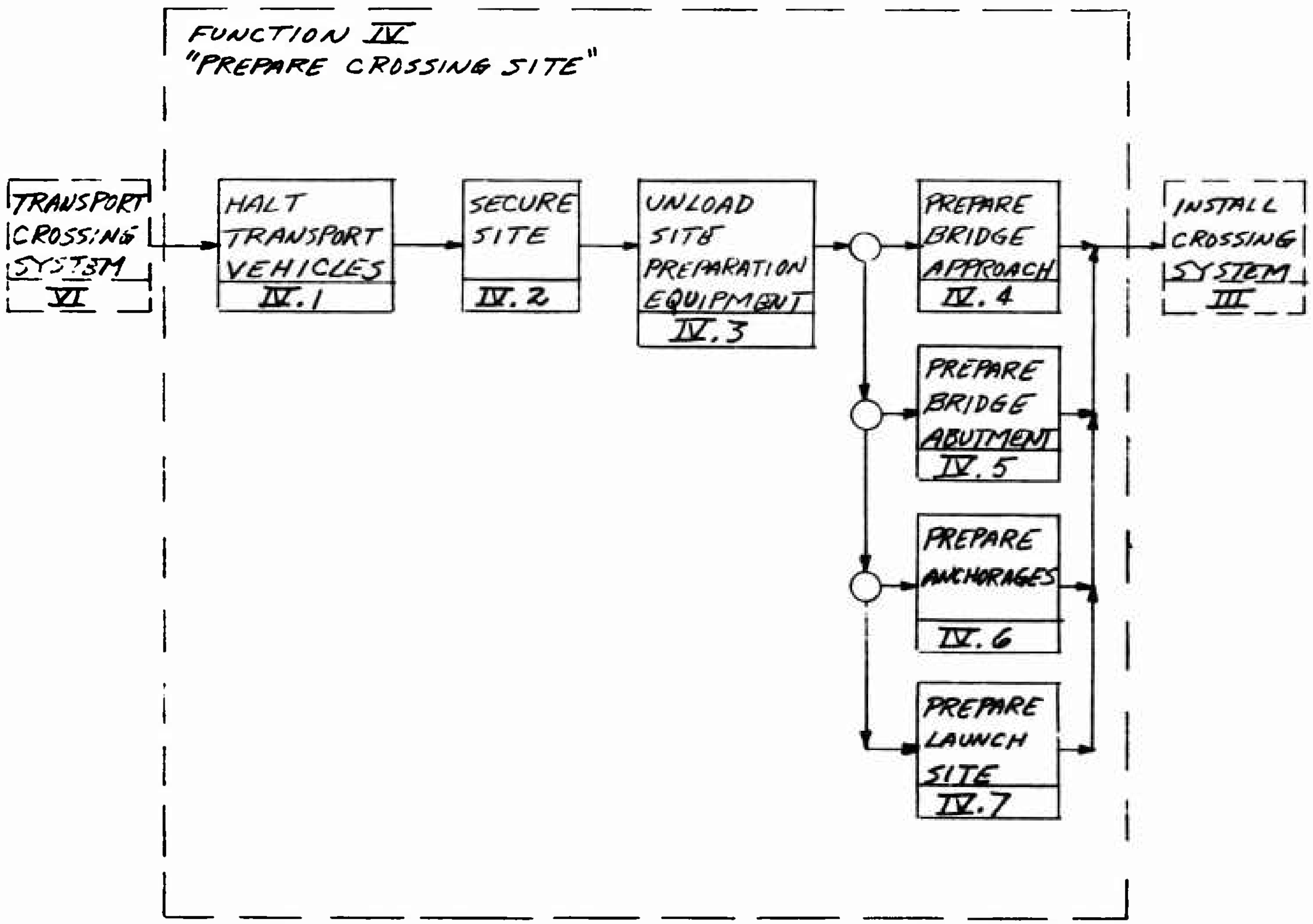

Fig. A-3. Prepare crossing site function flow block diagram, first level.

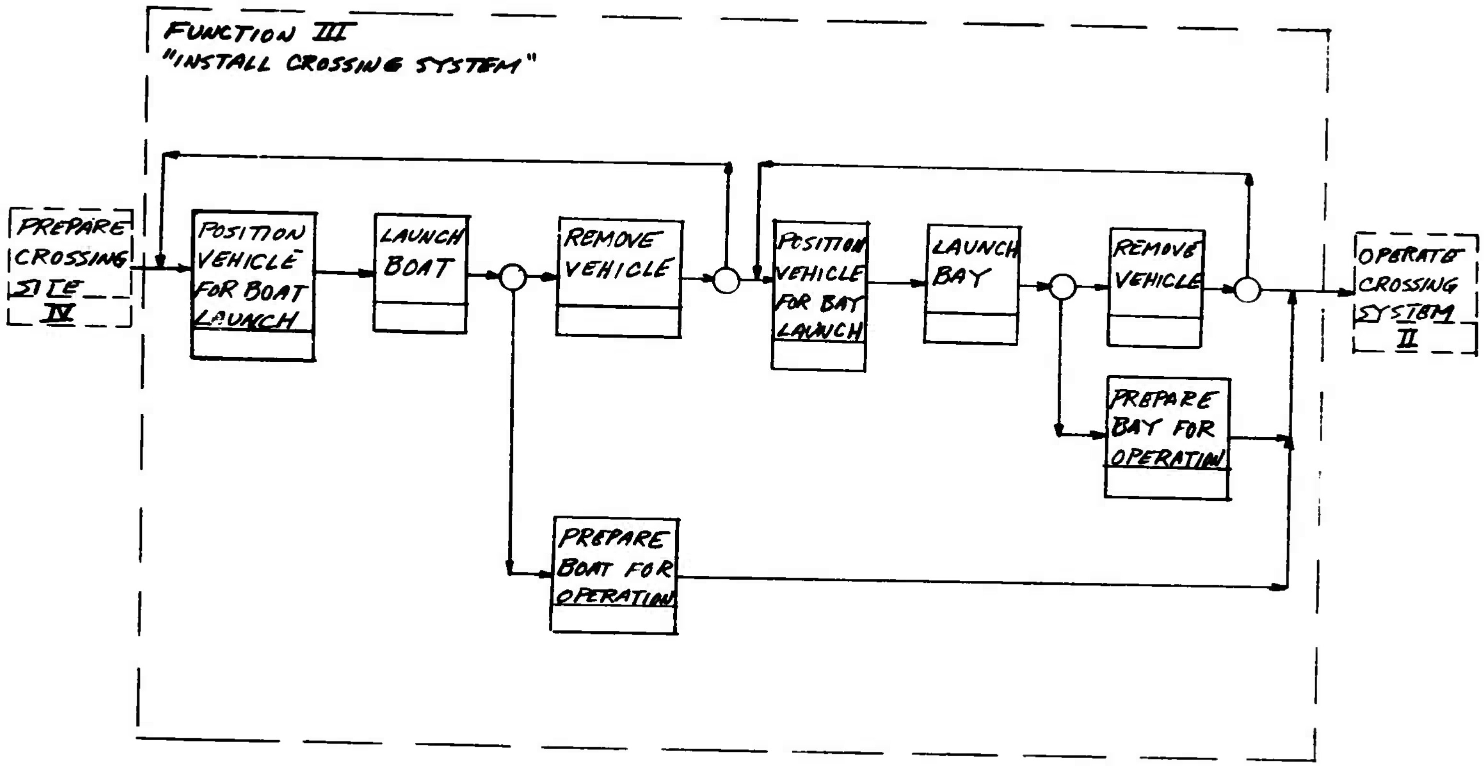

Fig. A-4. Install crossing system function flow block diagram, first level.

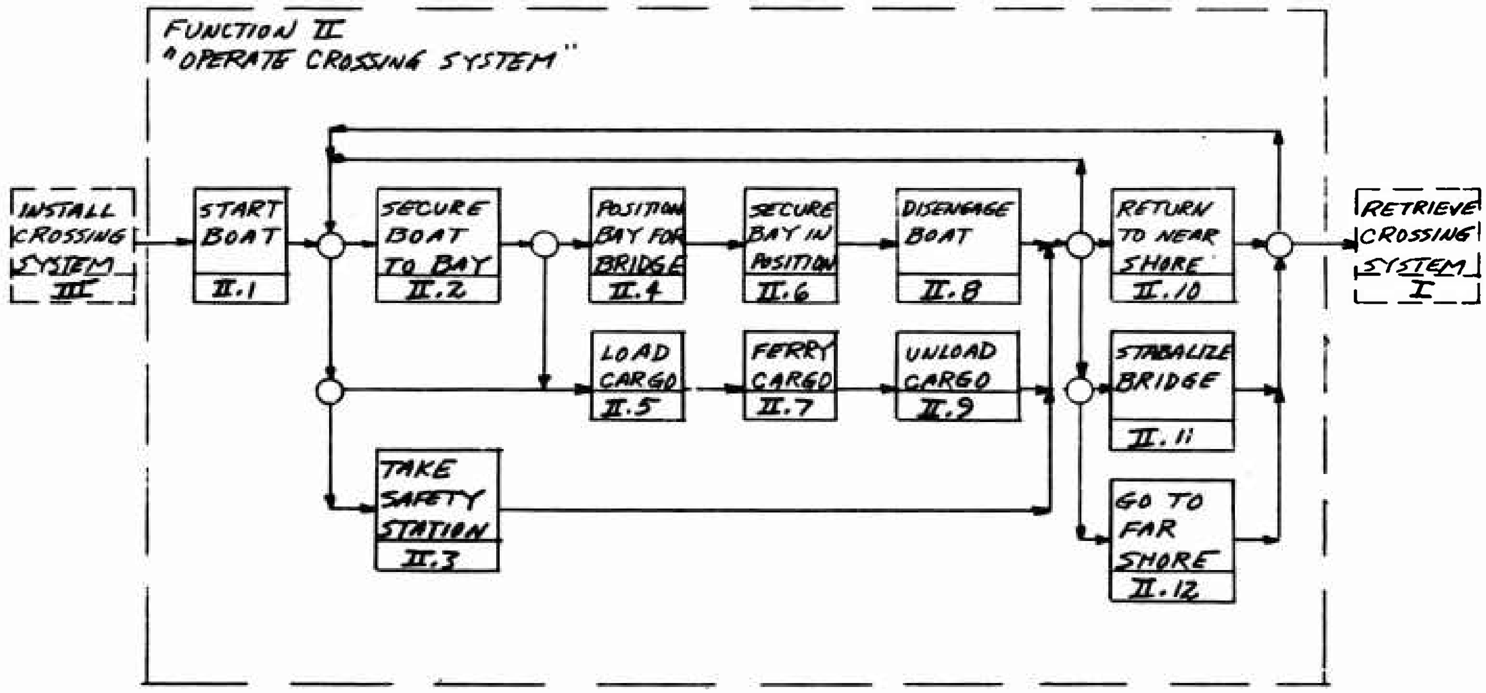

Fig. A-5. Operate crossing system function flow block diagram, first level.

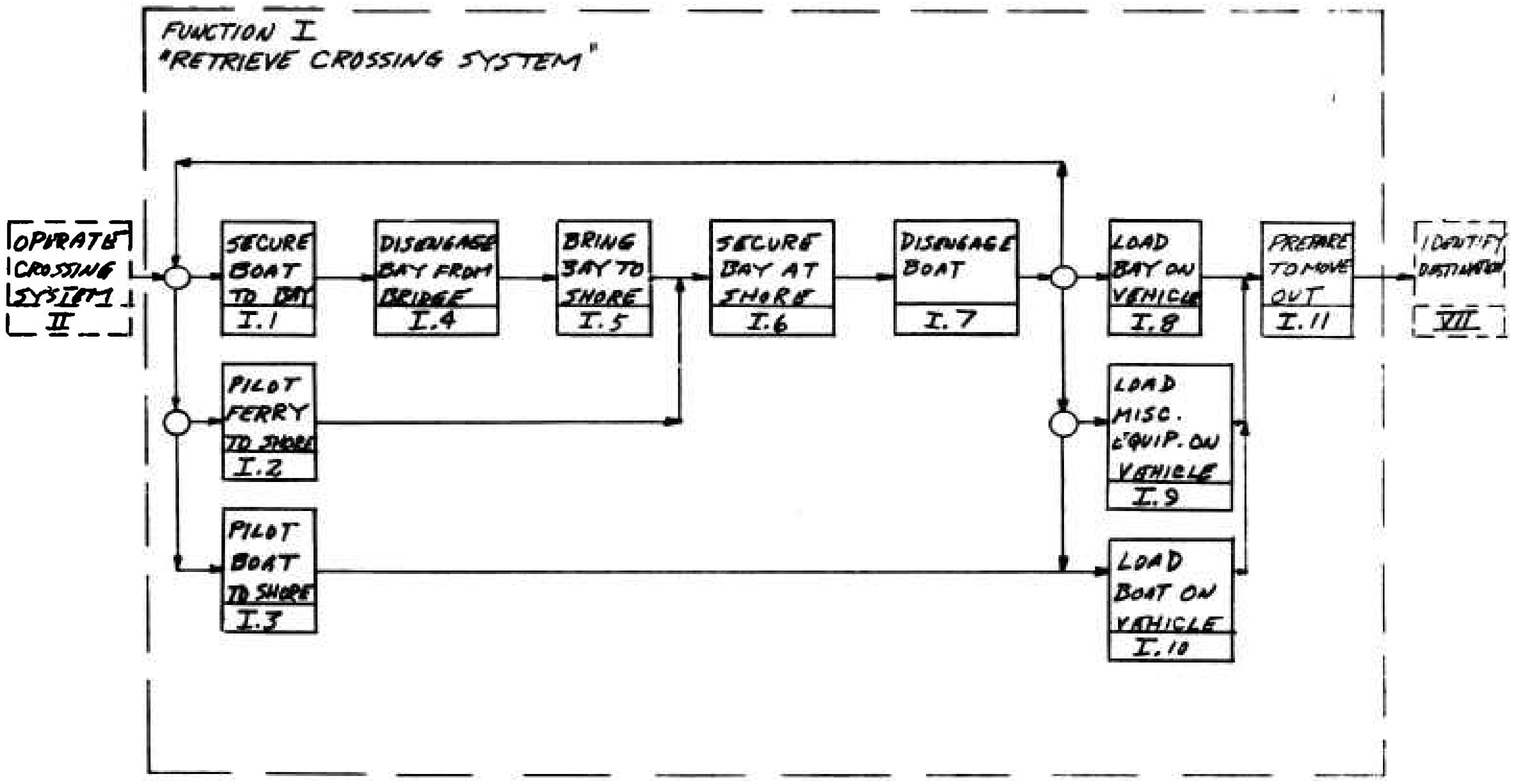

Fig. A-6. Retrieve crossing system function flow block diagram, first level.

APPENDIX B

DEFINITION OF TERMS

1. Initial Deployment Mobility
2. Field Mobility
3. Scheduled Maintenance
4. Check Out Time
5. Repair Time
6. Mean Time Between Maintenance Actions
7. Commonality
8. Deadline
9. Maintainability
10. Mean Time Between Failures
11. Degradation Modes
12. Mean Time Between Overhauls
13. Accident Susceptibility
14. Vulnerability to Enemy Action
15. Time
16. Number of Troops Required
17. Simplicity
18. Adaptability
19. Speed–On Road
20. Speed–Off Road
21. Turn Radius
22. Width
23. Length
24. Weight
25. Driver Skill
26. Logistics Factor
27. Endurance Factor
28. Compatibility

1. **Initial Deployment Mobility.** Initial deployment mobility is defined as meaning mobility within CONUS and from CONUS to OCONUS, basically from manufacturer to a CONUS or OCONUS Army depot. Time is important but seldom critical. A wide range of handling equipment is usually available, and manpower is, in most cases, abundant and working on a full-time basis. The modes of transportation include land, sea, and air, both military and civilian, and are usually conventional in nature. Land transportation will generally consist of rail and/or truck and/or self propulsion on railroads, roads, or highways. Sea

transportation consists primarily of military or civilian cargo ships, and air cargo planes are employed for the air mode. In all of these methods, the transportation equipment has been developed, modified, and improved over the years to move all reasonable weights, sizes, and shapes of equipment over established routes under standard operating procedures.

2. **Field Mobility.** Field mobility will be from the CONUS or OCONUS depot to the using field forces and then to destruction or return to depot. Although some generalized planning and scheduling is done in anticipation of various situations, there is little or no lead time during emergencies. The surfaces traversed may range from good roads to cross-country in swamp, desert, or mountains. In many phases of field mobility, the least mobile, necessary piece of equipment will determine the areas and speed of practical deployment of the entire system. In addition, the time and environment required to launch the most difficult piece of equipment is the pacing function for system employment.

3. **Scheduled Maintenance.** Maintenance is defined as all actions necessary for retaining an item in or restoring it to a specified condition. Preventive maintenance is defined as actions performed in an attempt to retain an item in a specified condition by providing systematic inspection, detection and prevention of incipient failure. Scheduled maintenance is used in this study to denote maintenance at established intervals of time.

4. **Checkout Time.** This term is defined as the time required for tests or observations that are necessary to determine the condition or status of an item.

5. **Repair Time (Corrective Maintenance Time).** This item is defined as the time required to accomplish the actions that are necessary to restore an item to a specified condition after failure.

6. **Mean Time Between Maintenance Actions.** This term is defined as the mean of the distribution of the time intervals between maintenance actions (either preventive, corrective, or both).

7. **Commonality.** This term, for this study, denotes the degree of interchangeability of elements of the subject systems with other elements of the entire Army system.

8. **Deadline.** This item definition covers all system downtime regardless of cause.

9. **Maintainability.** This term is defined as a characteristic of design and installation which is expressed as the probability that an item will be retained in or restored to a specified condition within a given period of time, when the maintenance is performed in accordance with prescribed procedures and resources.

10. **Mean Time Between Failures (MTBF).** This term is defined as the total functioning life of a population of an item divided by the total number of failures within the population during the measurement interval.

11. **Degradation Modes.** As used in this study, the term refers to the routes by which any of the system elements (i.e., hardware, facilities, personnel, procedural data) can fail.

12. **Mean Time Between Overhauls (MTBO).** In this study the term refers to major scheduled maintenance.

13. **Accident Susceptibility.** This term is defined as the probability of system damage caused by either human or mechanical error. These errors may result from improper training, fatigue, too stringent mission requirements, inadequate quality control, etc. The results of enemy action are not included in this definition.

14. **Vulnerability to Enemy Actions.** This term is defined as the probability of system damage from any and all forms of enemy action.

LAUNCHABILITY/RETRIEVABILITY

15. **Time.** This term is defined as the time required to get a boat from the travel mode to the operational mode (launch) and from the operational mode to the travel mode (retrieval).

16. **Number of Troops Required.** This item encompasses the total number of troops required to launch and retrieve a boat using each of the systems under consideration.

17. **Simplicity.** For the purpose of this study, this is defined as the reciprocal of the number of steps required to launch and to retrieve.

18. **Adaptability.** This item is defined as the degree to which the difference in time required to launch or retrieve in the worst scenario and the best scenario

approaches zero ($T_{ws} - T_{bs} = 0$). The more closely the difference approaches zero, the more adaptable the system is defined to be.

MOBILITY

19. **Speed – On Road.** This is defined as the usual or expected on-road speed in miles per hour.

20. **Speed – Off Road.** This item is defined as the usual or expected cross country speed in miles per hour.

MANEUVERABILITY

21. **Turn Radius.** This is defined as the shortest turning radius of which a vehicular system is capable.

22. **Width.** This item is defined as the maximum overall width of the widest part of the system under consideration.

23. **Length.** This item is defined as the maximum overall length of the system being considered.

24. **Weight.** This item is defined as the maximum total system weight.

25. **Driver Skill.** This item is defined as the degree of driving skill necessary to satisfactorily drive the system. The lower the skill requirements, the higher the effectiveness rating for a given system.

26. **Logistics Factor.** For the purpose of this study, the logistics factor is defined as the reciprocal of the number of components in the system.

27. **Endurance Factor.** The endurance factor pertains to the period of time between deployment and disposal. It includes storage, standby, up time, and downtime. Design, environment, maintenance procedures, and usage influence the endurance factor. In most cases relative, rather than absolute, endurance life determines the advantage or disadvantage of a system in this term.

28. **Compatibility.** This term is defined as the degree of capability of system elements to function as elements of other bridge systems.